

Mineral Carbonation of CO₂

Eric H. Oelkers¹, Sigurdur R. Gislason² and Juerg Matter³

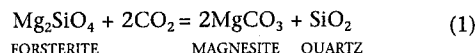
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A survey of the global carbon reservoirs suggests that the most stable, long-term storage mechanism for atmospheric CO₂ is the formation of carbonate minerals such as calcite, dolomite and magnesite. The feasibility is demonstrated by the proportion of terrestrial carbon bound in these minerals: at least 40,000 times more carbon is present in carbonate rocks than in the atmosphere. Atmospheric carbon can be transformed into carbonate minerals either *ex situ*, as part of an industrial process, or *in situ*, by injection into geological formations where the elements required for carbonate-mineral formation are present. Many challenges in mineral carbonation remain to be resolved. They include overcoming the slow kinetics of mineral-fluid reactions, dealing with the large volume of source material required and reducing the energy needed to hasten the carbonation process. To address these challenges, several pilot studies have been launched, including the CarbFix program in Iceland. The aim of CarbFix is to inject CO₂ into permeable basaltic rocks in an attempt to form carbonate minerals directly through a coupled dissolution-precipitation process.

KEYWORDS: CO₂ sequestration, mineral carbonation, mineralogic storage, basalt carbonation

INTRODUCTION

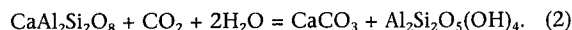
Mineral carbonation is the fixation of CO₂ as stable carbonate minerals, such as calcite (CaCO₃), dolomite (Ca_{0.5}Mg_{0.5}CO₃), magnesite (MgCO₃) and siderite (FeCO₃) (Metz et al. 2005). Insight into the potential effectiveness of storing atmospheric CO₂ as carbonate minerals is demonstrated by the relative volume of these reservoirs worldwide. The total mass of carbon currently in the atmosphere is approximately 800 gigatons (Gt). In contrast, ~39,000,000 Gt of carbon are currently present in carbonate rocks, such as marble, limestone and chalk, in the Earth's crust (cf. Oelkers and Cole 2008 this issue). In nature, the formation of carbonate minerals from atmospheric CO₂ is one of the major processes in the long-term global carbon cycle (Berner et al. 1983). Gaillardet et al. (1999) stated that about 0.1 Gt of carbon per year is bound by silicate-mineral weathering throughout the world; at this rate, the global atmospheric CO₂ inventory would be consumed after about 8000 years.



FORSTERITE

MAGNESITE QUARTZ

and



ANORTHITE

CALCITE

KAOLINITE

Such reactions have been observed in nature and in the laboratory (e.g. Giammar et al. 2005; McGrail et al. 2006). An alternative to the formation of divalent-cation carbonate minerals, which could eliminate the risk of forming pore-clogging Al-bearing clay minerals, is dawsonite [NaAl(CO₃)(OH)₂], but this compound has high reactivity and relatively low stability, so it is not a good candidate for long-term CO₂ storage (Hellevang et al. 2005; Bénézech et al. 2007).

EX SITU MINERAL CARBONATION

Although the formation of stable carbonate phases by reacting CO₂ with silicate minerals is thermodynamically favourable, it is not straightforward on an industrial scale. There are three major challenges: (1) the mammoth scale of an *ex situ* CO₂ mineralization effort, (2) the need to accelerate the rate of carbonate formation to make it efficient and (3) the large energy costs (cf. Rubin 2008 this issue).

Scale

According to the U.S. Environmental Protection Agency (EPA) E-Grid, an average coal-fired power plant produces 4 million MWh of electricity per year (DOE/EPA 2000). Coal power plants in the US produce approximately one metric

¹ Biogéochimie et Géochimie Expérimentale
LMTG-Université de Toulouse-CNRS-IRD-OMP
14 av. Edouard Belin, 31400 Toulouse, France
E-mail: oelkers@lmtg.obs-mip.fr

² Institute of Earth Sciences, University of Iceland
Sturlugata 7, Askja, 101 Reykjavik, Iceland
E-mail: sigrg@raunvisi.is

³ Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W, P.O. Box 1000, Palisades
New York 10964-8000, USA
E-mail: jmatter@ldeo.columbia.edu



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